WHERE ARE THE COOKIES? THREE-YEAR-OLDS USE NUMBER-MARKED VERBS TO ANTICIPATE UPCOMING NOUNS

BY

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THESIS

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ABSTRACT

This study examines the development of incremental parsing processes in language comprehension by testing 3-year-olds' use of a particular morphosyntactic dependency: number agreement between a subject and verb in English. Using a looking-while-listening paradigm, we show not only that children make use of this dependency during online comprehension, but also that children use it predictively to anticipate the number features of an upcoming noun. Children were both faster and more likely to switch gaze away from a mismatching distractor picture when they heard an informative agreeing verb (*is/are*). This is both one of the earliest demonstrations that children are able to use verb agreement alone as a cue to the semantic number of the subject, and one of the first pieces of evidence that children engage in predictive processing of language.

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Introduction

As adults read or listen to their native language, they process the linguistic input incrementally. That is, they use each piece of information as soon as it is available, to rapidly retrieve linguistic knowledge, determine the best analysis of the linguistic material encountered to that point, integrate the incoming information with the current structure, and make predictions about upcoming elements (Marslen-Wilson, 1975; Frazier & Fodor, 1978; Altmann & Steedman, 1988; Federmeier, 2007; Kamide, 2008). During incremental processing adults take advantage of both bottom-up information from the phonology, lexical items and morphosyntax and top-down information from the referential and discourse context (e.g., Dahan, et al., 2000; Garnsey, et al., 1997; Marslen-Wilson & Zwitserlood, 1989; Tanenhaus, et al, 1995). This process is unconscious and automatic.

How does children's online comprehension compare to adults'? Do children use the same cues in the same way? Do they also engage in prediction? Here we investigate the development of incremental processing, focusing on children's use of a particular morphosyntactic cue: subject-verb agreement.

Our goals in investigating children's use of this cue are twofold. First, we hope to expand on previous research examining what morphosyntactic cues children use in online comprehension, by testing what is arguably a more demanding case than has previously been studied: subject-verb agreement. The same features that make this dependency more demanding also enable us to address our second goal: determining the nature of children's online sentence processing. Do children, like adults, predict upcoming material during sentence comprehension? Each of these goals will be discussed in turn.

Online Use of Morphosyntactic Cues

Many experimental studies establish that children process language incrementally, at multiple linguistic levels. For example, 2-year-olds use phonological cues incrementally during word recognition: they take longer to identify a named target picture when presented with target and distractor pictures whose names share an onset (*dog-doll*), compared to pairs that rhyme (*ball-doll*; Swingley, Pinto & Fernald, 1999). Similarly, the presence of a known determiner aids children's sentence comprehension, and speeds their recognition of the following noun (Gerken & McIntosh, 1993; Zangl & Fernald, 2007; Kedar, Cassasola & Lust, 2005; van Heugten & Johnson, 2010). Children are faster and more accurate at identifying a familiar noun, if it is preceded by a familiar determiner (*Where is the shoe?)* in contrast to no determiner (*Where is shoe?*), a novel determiner (*Where is loo shoe?*) or a familiar, non-determiner function word (*Hand me was shoe.*). This tells us that children are sensitive to the typical order of syntactic categories within the noun phrase in their language (determiner, then noun), and that they can use this information during online comprehension to ease and speed their processing.

Another study tested children's use of more refined morphosyntactic information, by examining Spanish-learning children's ability to use a gender-marked determiner to speed recognition of the subsequent noun (Lew-Williams & Fernald, 2007). The gender-marking on the determiner indicates not only that a noun is coming, but that the upcoming noun belongs to a particular subcategory (masculine or feminine nouns). In this study, children were faster to look to the target picture (e.g., *la pelota*, “the ball”) when the name associated with the distractor picture differed from the target in grammatical gender (e.g., *el zapato*, “the shoe”) compared to trials in which the distractor matched the target in grammatical gender (e.g., *la galleta*, “the cookie”). In a similar study 25-month-old French-learners' word identification was fastest and most accurate in the context of a different-gender distractor, accurate but slower in the context of a same-gender distractor, and disrupted when the target noun was preceded by a wrong-gender determiner, not recovering even by the end of the trial (van Heugten & Shi, 2009). These findings suggest that children are sensitive, not just to the relevant order information at the broad level of syntactic category, but also to the subcategories: the dependency between the form of the determiner and the gender of the noun.

Do children use morphosyntactic cues other than the determiner in online comprehension? The studies reviewed above examine gender agreement between determiners and nouns, but in some ways this is a special case. First, grammatical gender is a lexical property of each noun (Corbett, 2006, p. 126). This means that, in Spanish for instance, a given word will always be either masculine or feminine, and any time a particular word occurs with a determiner, that determiner will show the same agreement features. Second, the syntactic relationship between the two words is quite local, occurring within the noun phrase. Though they can be separated (e.g., by adjectives: *la nueva pelota*), the range of categories than can intervene is restricted, and many of the intervening items themselves show agreement. Together, these facts mean that gender-marked determiners and nouns have a highly consistent distributional pattern, and typically appear adjacent to one another. Research using artificial language learning suggests that this consistency and adjacency should make them comparatively easy for children to acquire (Saffran, Aslin & Newport, 1996; Gómez, 2002; Gómez & Maye, 2005; Newport & Aslin, 2004).

Languages are characterized by a wide variety of dependencies, many less local and consistent than the intimate relationship between a determiner and noun. One such example is agreement between a subject and verb. Subject-verb agreement in English, in particular, might pose more of a challenge to learners. In contrast to Spanish determiner-noun agreement, English subject-verb agreement is based on grammatical number, which is not associated with particular nouns, but varies with the speaker's intended message (Corbett, 2006, p. 130). The form of a regular English noun that speakers choose depends on the number of entities they intend to refer to: for more than one dog, for example, they will choose the form *dogs*, for a single entity, *dog.* This choice then influences the form of the verb (e.g *dogs are* vs. *dog is*). Furthermore, subject-verb agreement spans two major constituents of the sentence: the subject noun phrase and the verb. This means that the subject and its agreeing verb can be separated linearly by long phrases (e.g., *The <u>cookies</u> with chocolate chips that I left in the oven for much too long <u>were</u> burnt*.), and can even have their order reversed in common constructions such as questions (*Where <u>are</u> the good <u>cookies</u>?*) and locative inversions (*There are the good cookies!*). Finally, overt marking of subject-verb agreement in English is quite sparse. Table 1 shows the regular and irregular agreement paradigm for English verbs. For regular verbs, only the third-person singular form is marked by an overt affix, and even irregular verbs have a limited agreement pattern. Overall, this means that subject-verb agreement in English has a distributional pattern both less well marked and more varied than that of gender agreement in a language such as Spanish. The agreeing elements in the case of verb agreement are also frequently non-adjacent. Studies of artificial grammar learning suggest that all of these elements make noticing and learning a dependency more difficult

(Saffran, Aslin & Newport, 1996; Gómez, 2002; Gómez & Maye, 2005; Newport & Aslin, 2004).

Finding evidence that children do use verb agreement in online language comprehension would suggest that children use a wide variety of morphosyntactic cues incrementally. Furthermore, because of its flexibility in distance and order, testing children's use of subject-verb agreement will allow us to address our second goal.

Prediction

For adults, expected information is easier to process. When a word is presented in a supportive semantic context (e.g., *The barber trimmed the mustache.*), it requires less time to recognize (Tulving & Gold, 1963), it is less likely to be fixated during reading (Erlich & Rayner, 1981; Morris, 1994), and it will elicit faster naming and lexical decision times (Stanovich & West, 1979; Fischler & Bloom, 1979). Is this facilitation the result of easier *integration* with the preceding context (e.g., Marslen-Wilson, 1989), or of *prediction* based on context (e.g., McClelland & Rumelhart, 1981)? On one hand, it could be that once the semantic features of the expected item are accessed based on the bottom-up information from the word itself (i.e. the word's visual or auditory form), they share more properties with the preceding context and are easier to integrate into the representation being built. On the other hand, it could be that even before they begin to receive bottom-up information, listeners preactivate probable features of an upcoming word. This would allow them to get a 'head-start' on processing that word, giving them an advantage when bottom-up information from the expected word begins to arrive. Evidence suggests that prediction plays a role in language comprehension, but the extent of prediction is still controversial (for reviews see Federmeier, 2007; Kamide, 2008).

Either an integration or a prediction account would satisfactorily explain the observed advantage for expected material, and the two can be difficult to distinguish experimentally (Federmeier, 2007; Kamide, 2008). Measuring responses to the expected word itself allows a clear measure of how easy or difficult it is to process, but the key difference between prediction and integration accounts is the timing of processing with respect to the onset of bottom-up information from the expected word. In the case of integration, processing begins with the onset of bottom-up information, while in the case of prediction, processing begins before any bottom-up information from the word has been encountered. Observing facilitation as participants process an expected word leaves considerable ambiguity about when that facilitation occurred.

There are two strategies for attempting to distinguish these accounts. First, many researchers examine differences in how participants process particular *unexpected* words in constraining contexts (e.g., Federmeier & Kutas, 1999). Second, researchers use measures at points before the onset of the expected word. Differences in eye-movements before the expected word (e.g., Altmann & Kamide, 1999), or ERP responses to a preceding word (e.g., Delong, Urbach & Kutas, 2005) can both provide evidence for prediction. Though both accounts make similar predictions for responses to an expected word, they predict different responses when certain unexpected words are encountered, or before bottom-up information begins to arrive.

There is strong evidence that prediction plays an important role in adults' language processing. Altmann & Kamide (1999), for instance, showed that adults given a visual scene (e.g., a boy, a train and a cake) and an auditory sentence stimulus (*The boy will eat/move the cake.*) looked to the appropriate object well before the onset of the noun itself, when it was preceded by a semantically constraining verb (e.g., *eat*). This suggests that participants anticipated that the speaker would name that object, rather than the distractor, even before they heard the noun itself. However, it is important to keep in mind that semantic associates of a target are fixated more than unrelated distractors, even when their semantic relationship is irrelevant to the task at hand (e.g., Huettig & Hartsuiker, 2008; Arias-Trejo & Plunkett, 2009). Similarly, participants might have looked more to the cake even if the word *eat* had been presented in isolation, by virtue of semantic association alone (Fernald, 2004). The prediction hypothesis makes a more specific claim: that listeners are predicting the appearance of a particular word as a continuation of the linguistic structure under construction. In this study, that would mean anticipating specifically that *the cake* will be the object of the verb.

Other studies have used different strategies to investigate predictive processing. For instance, adults reading unexpected words in a constraining context show an enhanced N400 component of the ERP (e.g., Kutas & Hillyard, 1983). However, this N400 can differ between two equally unexpected words. For instance, given a sentence that sets up an expectation for the word *palms* (e.g., *They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of...*), the word *pines*, which belongs to the same semantic category as the expected word, elicited a smaller N400 than an unexpected word from a different semantic category (*tulips*), suggesting that relevant category features of the expected word had been preactivated (Federmeier & Kutas, 1999). Enhanced N400 responses can even be observed at words preceding, but dependent on the expected word. For instance, Delong, Urbach and Kutas (2005) took advantage of the different forms of the indefinite determiner in English (a vs.

an). They presented participants with sentences such as *The day was breezy, so the boy went outside to fly* [*a kite/an airplane*]. They observed a larger N400 both to the unexpected noun (*airplane*), and to the unexpected form of the determiner (*an*). This suggests that participants predicted the upcoming word in highly constraining contexts, and did so with enough specificity to anticipate the appropriate phonologically conditioned form of the determiner. Thus, during incremental processing, adults not only integrate the linguistic material they encounter with the preceding context, but actively anticipate possible upcoming items.

Though children process language incrementally, they are slower and less accurate in identifying words than adults are (Swingley, Pinto & Fernald, 1999). On one hand this makes it seem unlikely that they would make predictions during online comprehension, as adults do. Making a prediction means processing the relevant cues and using that information to anticipate an upcoming element. If children are unable to identify the cue and retrieve relevant information quickly enough, they may not arrive at a prediction before bottom-up information about the expected element begins to arrive. Furthermore, children are still in the process of learning the grammatical dependencies that could support prediction. It may be that it is difficult for children to use recently or incompletely acquired cues in prediction.

On the other hand, some models of language acquisition suggest that prediction plays an important role in learning (e.g., Elman, 1990; Chang, Dell and Bock, 2006). These models propose that for learners a key source of data about the grammar is the continuous use of linguistic knowledge to make predictions about upcoming elements, followed by observation of the success or failure of these predictions. The more efficiently and frequently children are able to make predictions, even inaccurate ones, the more learning opportunities they will be able to take advantage of. On this theory, then, children would regularly make predictions during online comprehension.

Does the existing literature provide any evidence that children make predictions during online language processing? Studies of children's incremental processing are suggestive, but typically do not allow enough time to clearly distinguish prediction from integration. For instance, studies of children's use of phonological cues are designed to ask how children use the bottom-up information about the phonology of a word to narrow down the possible referents (Swingley, Pinto & Fernald, 1999). Studies that address children's use of morphosyntactic cues typically focus on the relationship between adjacent determiners and nouns (e.g., Gerken & McIntosh, 1993; Zangl & Fernald, 2007; Lew-Williams & Fernald, 2007), leaving no time to observe an effect of prediction from one to the other. One study investigating children's use of semantically restrictive verbs (e.g., *eat*, *drink*), however, provides a suggestion that children do predict upcoming information. When 26-month-olds hear sentences like *You can drink the juice* while looking at two pictures, one showing a glass of juice, and one showing an unrelated object, they look significantly more to the juice than the distractor well before the onset of the noun itself, and much earlier than in similar trials with a semantically unrelated verb (e.g., *see*, *take*; Fernald, et al., 2008). However, as noted above regarding similar evidence for adults' use of semantically restrictive verbs (Altmann & Kamide, 1999), an alternative interpretation of these results relies on the semantics of the verb itself to drive eye-movements, not on the relationship between the verb and object in the sentence at hand. Thus, while prediction has the potential to be an excellent source of data for children during the course of language acquisition, evidence for children's use of prediction remains weak.

The Present Study

The present study examined children's online comprehension of subject-verb agreement, taking advantage of the syntactic distance between the dependent elements to seek evidence of prediction based on the number-marked verb (e.g., *Where are the good cookies?*). Children viewed pairs of pictures that differed in their number of depicted objects (e.g., a picture of two cookies, and a picture of one apple, as shown in Figure 1), accompanied by audio stimuli directing them toward one picture or the other. Half of these test sentences included a number-marked verb (e.g., *Where are the good cookies?*, informative trials), and half did not (e.g., *Can you find the good cookies?*, uninformative trials). This design permitted us to compare the effect of a number-marked verb on visual fixations to the same images. If children can use an agreeing verb (*is*/*are*) to predict the number features of the upcoming noun, they should look away from a picture showing the wrong number of objects when they hear the verb, even before getting bottom-up information about the noun itself. Because the informative and uninformative trials used different recorded sentences, we compared this experimental condition to a control condition in which children heard the same sentences, but saw pictures that matched in number on every trial (e.g., a picture of two cookies, and a picture of two apples). In this context, the number-marked verb is no longer informative, and children should be no quicker to look at the target during sentences with a number-marked verb than during those without.

This task depends on a number of prerequisites. In order to show signs of incremental processing in this task, children must (a) be familiar with the dependence of the verb form on the grammatical number of the subject, (b) be able to infer the real-world number of objects from some combination of the linguistic cues in the sentence, and (c) use the relationship between the agreeing verb and its subject noun to ease their comprehension of the sentence. In order to show signs of prediction, they must (d) use the number-marking on the verb to infer the number of the noun before bottom-up information about the noun begins to arrive.

We know from previous research that children are sensitive to the morphological dependency between a subject and verb. Children as young as a year and a half old are already familiar enough with the distributional patterns of their language to distinguish between certain clearly-marked grammatical and ungrammatical agreement patterns, though it is unlikely that they attach any meaning to the patterns at this age. Seventeen-month-old French-learners and 19-month-old English-learners both prefer to listen to grammatical patterns of agreement, where the noun and verb affixes occur in appropriate pairings (French, *La fotiste est parfois...* vs **Les fotiste(s) est parfois...*, van Heugten & Shi, 2010; English, *A team bakes bread.* vs **A team bake bread.,* Soderstrom, Wexler & Jusczyk, 2003). Note that in the French examples, children track the grammaticality of the relationship between the determiner (either singular, *la*, or plural, *les*) and the agreeing verb (singular, *est*) even across novel nouns, suggesting that children's knowledge of the dependency is represented independently of particular nouns. Thus, even toddlers are sensitive to some of the distributional facts showing the dependency between the form of the subject and the form of the verb.

Other research shows that 24-month-olds can use linguistic cues to determine semantic number. In a preferential looking study, children used sentences with grammatical number redundantly signaled by a verb, a quantifier, and number marking on the noun (*There is a blicket_* vs. *There are some blickets*) to determine whether a novel word referred to a single novel object or a set of objects (Kouider, Halberda, Wood & Carey, 2006). Children looked longer at the correct than the incorrect picture for both singular and plural sentences. Interestingly, this study also yielded preliminary evidence of the online use of verb agreement. The authors observed that children's looks to the correct picture began to differ from chance very shortly after the verb, suggesting that the form of the verb may have triggered children's increased looking to the target. However, because the verb was immediately followed by an informative quantifier, which may have driven or significantly contributed to children's tendency to look to the target, it is difficult to determine the precise source of this early effect.

Studies of children's use of number-marked verbs as the only cue to grammatical number have shown a more mixed pattern of results. Some studies have shown that children fail to use a number-marked verb as an indicator of noun number until 5 or 6 years of age (Johnson, de Villiers & Seymour, 2005; deVilliers & Johnson, 2007), well after children have begun producing these forms in their own speech (e.g., Brown, 1979; Theakston, Lieven & Tomasello, 2003), whereas in others 3- and 4-year-old children succeed. For instance, a recent study showed that German-learning 3- and 4-year-olds looked longer to the appropriate picture, given a sentence disambiguated by verb-number alone (e.g., *Sie füttert einen Hund*. "She's feeding the dog."/*Sie füttern einen Hund*[1]. "They're feeding the dog", Brandt-Kobele & Höhle, 2010; see Legendre, et al., 2010, for

[1]Note that the third-person feminine singular and plural pronouns are homophones in German, so the difference between *she* and *they* in these sentences is marked only by agreement on the verb.

a similar result with French-learning 30-month-olds). Additionally, in the study with German children, they succeeded when they were only asked to look at the screens. When asked to point to the correct picture, children did not show an effect of verb number in either their looks or their pointing behavior. Thus, finding evidence that children are able to use subject-verb agreement alone as a cue to semantic number has been difficult. Some of this difficulty appears to be attributable to problems with methodology, but recent studies suggest that by approximately 3 years of age, and perhaps earlier, children are capable of using linguistic cues, sometimes including verb agreement alone, to infer the semantic number of the subject.

Young children appear to have the requisite knowledge to succeed in our task. They are sensitive to the distributional patterns of subject-verb agreement, and they can use linguistic information to make inferences about notional number, even when verb number is the only available cue. What remains is to determine whether children are able to use the morphosyntactic information provided by a number-marked verb during online comprehension, and if so, whether they do so predictively.

Method

Participants

Participants were recruited from the area around Champaign-Urbana, Illinois, and were predominately from white, middle-class families. Sixty-four 3-year-olds (mean age = 37.8 months, range = 34.2-42.4 months; 32 girls, 32 boys) participated, 32 each in the experimental and the control groups. All were learning English as their primary language (< 25% exposure to another language, by parental report). Five additional children were eliminated due to a reported language delay (1), declining to be tested in a darkened room (1), or because too few trials could be included due to inattentiveness or parental interference (3; see Coding below). Children's productive vocabularies were measured with the short form of the MacArthur-Bates Communicative Development Inventory (Level III; Fenson, et al. 2000), and ranged from 12 to 99 (median = 75).

Stimuli

Auditory stimuli were simple sentences and questions ending in one of eight familiar nouns *(doggie, baby, kitty, turtle, bike, truck, apple, cookie*). Sentences were of two types: Informative sentences that included a potentially informative number-marked verb before the noun, and Uninformative sentences that did not[2]. Half of all sentences directed children's attention to plural targets, and half to singular targets. See Figure 1 for an example. In all sentences, a familiar adjective (*good, nice, pretty,* or *new*) preceded the noun. This separated the number-marked verb from the agreement-controlling noun in informative sentences, allowing time in which to observe anticipatory effects in

[2]Because we observed a plural bias when informativeness was manipulated visually within participants in a pilot study (*Where are the good cookies?* in the context of either one apple and two cookies, or two apples and two cookies), we used a linguistic manipulation to control informativeness in the final version.

children's eye-movements. A female native speaker of American English recorded the sentences in a child-directed style. Tokens were chosen to be high-quality recordings that were similar in overall duration, the duration of the critical determiner-adjective region before noun onset, and in prosodic contour. The mean duration of the sentence frame (i.e. *There is/are, Where is/are, Can you find, Oh, look at*) across sentences was 730 ms (range 633-1333ms), mean duration of the determiner and adjective region was 575 ms (range 433-700 ms), and mean target-noun duration was 508 ms (range 200-833 ms, singular mean = 401 ms, plural mean = 618 ms). Test sentences were followed by tag questions (e.g., *Do you see it?*, *Do you like them?*) with varying intonation to help hold children's interest. Three filler trials were interspersed among the 32 test trials. The visual stimuli were photographs of the objects and animals named by the target nouns. Pictures appeared in yoked pairs (dog-baby, cat-turtle, bike-truck, apple-cookie), and each picture served as the target on 4 test trials and the distractor on 4 test trials, with side and plurality of target picture counterbalanced within item pair.

Apparatus and Procedure

We used the looking-while-listening procedure (Fernald et al., 2008) in this study. Children sat on their parent's lap, 4 feet away from a single 50-inch, wide-screen television. Pictures were displayed in two locations (each 11 ¼" tall x 17 ½" wide) on the screen, aligned with the left and right edges of the screen and separated by 8 inches of black space. Audio stimuli were played from the television's internal speakers. A hidden camera just beneath the center of the television recorded children's eye-movements. Parents wore opaque glasses.

On each trial, two pictures appeared, one in each of the two screen locations. One picture showed a single object, and the other, a pair of identical objects. Pictures remained on the screen for 7 s; speech onset was approximately 2 s after the pictures appeared. The test sentence was followed by a tag question (e.g., *Do you see it?*, *Do you like them?*) to help hold children's attention. The testing session began with one practice trial in which two pictures were displayed (boat, airplane), and children were directed to find one or the other. Target and match side for the practice trial were counterbalanced across participants. This was followed by the 32 test trials, in which children saw two pictures, one singular and one plural, and heard either a sentence with a potentially informative verb or an uninformative sentence. One sequence was created by randomizing trials within each half of the study, such that the same yoked pair of pictures never appeared on consecutive trials, plurality, informativeness and match side were never repeated on more than three consecutive trials, and the first and last three trials did not match on any of these dimensions. Each half of the sequence of 32 trials contained equal numbers of each target noun, match side, plurality and informativeness. Trials were presented in one of eight lists, which were created by crossing order (the sequence described above, or its reverse), picture side (what half of the participants saw on the right, the other half saw on the left) and target (for a particular display, half of the participants heard one object named, and the other half heard the other named). This means that each child saw 16 trials in each condition (informative and uninformative), with an equal number of singular and plural targets in each condition.

Coding

We coded where children looked (right, left, or away from the test pictures) during each 7 s trial, frame by frame from silent video. Reliability was assessed for 22%

of children (n = 14); coders agreed on 96% of video frames. Any trials on which coders agreed on fewer than 90% of frames were coded by a third coder (n = 54 of 448, 12%). The third coder's data were used in the final data set. Individual trials were eliminated (192 of 2048 possible trials, 9.4%) if there were no data (i.e. the child was offscreen, or had decided to terminate the study early, n = 22), if the parent or child was talking (i.e. the parent talked during the test sentence, or the child talking about something other than the task during the test sentence, n = 74), or if children looked away for more than 50% of the 7 s trial (n = 96). Talking was assessed after the coding of children's looking behavior, by coders who watched the session video with the audio on, and recorded the timing and topic of any talking that occurred[3]. Any child for whom more than 4 of the possible 8 trials of a particular type (informative singular, informative plural, uninformative singular, uninformative plural) were excluded was eliminated from the sample (n = 3, see Participants, above).

Measures

To determine whether children used the information conveyed by the agreeing verb to orient more quickly to the target picture, we analyzed three different measures: the *reaction time* (RT) to shift gaze from distractor to target, the *shift probability*, or the probability of shifting gaze from distractor to target or from target to distractor before the onset of the noun, and *accuracy* measures based on the proportion of looks to the target. These measures are defined in more detail below.

Reaction time. If children can use an agreeing verb to speed their comprehension

[3]Ten of the 64 sessions were recorded without audio, due to experimenter error (n = 5) or equipment malfunction (n = 5). For these videos, coders watched the participants' mouths carefully and recorded the timing of all apparent talking. Using notes taken during the original session to determine the topic of the talking, trials were eliminated using the same criteria as above.

of a sentence, they should orient more quickly to the target picture when they hear an informative verb than when they do not. Reaction time (RT) is the latency of the first shift from the distractor to the target measured from a particular key frame (Fernald, et al., 2008). Our primary interest is in children's responses to the number-marked verb in informative sentences. However, because the uninformative sentences did not contain a verb in the same position, we anchored our reaction time measurements to the onset of the determiner, which was present in all sentences, and which immediately followed the number-marked verb in informative sentences. RTs were calculated for each trial in which children were looking at the distractor picture at determiner onset (experimental: 463 distractor-initial trials of 924 included trials; control: 430 of 929 trials), and switched to the target picture within a 1500 ms window beginning 100 ms after determiner onset. Traditionally, analyses of children's eye-movements exclude any shifts that occur less than about 300 ms after the stimulus of interest, to allow time for the planning of an eye movement (Fernald, et al., 2008). In informative trials, the number-marked verb began, on average, 206 ms before the determiner. Therefore, to exclude shifts that were initiated before the onset of the number-marked verb, we excluded all shifts that occurred within 100 ms of determiner onset, and therefore within approximately 300 ms of average verb onset. If children used the agreeing verb to aid their processing of the number of the upcoming noun, then RTs in informative trials should be faster than those in uninformative trials, but only for the experimental group.

Shift probability. The 1500 ms window in which RT was measured encompassed the determiner, adjective and the noun, which means that any RT advantage would be equally compatible with a predictive or an integrative account of children's use of verb marking. In order to distinguish these hypotheses, we calculated a switch probability measure, the proportion of trials in which the child switched to the other picture during a determiner-adjective window (Thorpe & Fernald, 2006), a 767 ms window beginning 100 ms after determiner onset (thus approximately 300 ms after verb onset in informative trials) and ending 300 ms after the average onset of the noun. These proportions were calculated for both distractor- and target-initial trials. Before children received any information about which picture would be the target, they should switch between the pictures about equally in both conditions. However, if they used the number-marked verb predictively, children in the experimental group might have switched from the distractor to the target in informative trials even before hearing the noun itself. Thus, a larger distractor-to-target switch proportion in the determiner-adjective window, observed in informative trials for the experimental group, would indicate predictive use of verb number-marking. The predictions for target-initial trials in the same time region are quite different. Several findings suggest that neither children nor adults keep a detailed representation of an entire display in working memory, but rather interrogate it by moving their eyes to relevant areas when they need information (Swingley & Fernald, 2002; Ballard, Hayhoe & Pelz, 1995). If so, then there is no reason for children to suppress any baseline tendency to shift away from a number-matching picture in target-initial informative trials. It could have been that the other picture matched equally well. Therefore, we predicted that the likelihood of shifts from target to distractor would not differ across informative and uninformative trials in either group.

Accuracy. Finally, because the number-marked verb may also influence the *amount* of time children spend looking to one picture or the other, the proportion of time spent looking to the target picture was averaged across windows of interest during the test sentence: the 767 ms determiner-adjective window extending from 100 ms after the onset of the determiner (approx. 300 ms after the onset of the verb in informative test sentences) to 300 ms after the average onset of the target noun, and a target-noun window of equal length, beginning 300ms after the onset of the noun.

Results

Overall, children were quicker to direct their attention to the correct picture in the context of an informative number-marked verb. Figure 2 shows the time-course of children's fixations to the target picture as the sentence unfolded, plotted separately by trial type (informative vs. uninformative) and group (experimental vs. control). The x-axis shows time from average verb onset through both the determiner-adjective and the noun windows described above. The graph shows the proportion of all fixations that were directed to the target picture in each 33 ms time-interval. In all conditions, children tended to look about equally at the two pictures at the onset of the determiner, but in the experimental group, looks to the target rose more sharply in the informative than in the uninformative trials. No such difference between informative and uninformative trials appeared in the control group. This pattern suggests that when the number-marked verb was informative in the visual context, children used this information in their online comprehension of the sentence. In order to better understand how children use this information during online comprehension, we analyzed measures of reaction time, switch proportion and accuracy.

Reaction Time

Analyses of the latency of distractor-to-target shifts, measured as described in the Methods section, revealed that children switched to the target more quickly in informative trials, but only in the experimental condition, suggesting that they used the informative number-marked verb to speed their recognition of a subsequent noun. Figure 3 shows the mean reaction times in milliseconds for informative and uninformative trials in each group. Note that the uninformative trials for the experimental group pattern with both conditions in the control group, while the experimental group's informative trials are noticeably faster. This pattern was supported by a 2x2 mixed effects analysis of variance (ANOVA) with informativeness (informative vs. uninformative sentences) as a within-subjects factor, and group (experimental vs. control) as a between-subjects factor. This analysis revealed significant main effects of informativeness ($F(1,62) = 5.81$, $p = .019$), and of group ($F(1,62) = 5.36$, $p = .024$), and most important, a significant interaction of informativeness and group ($F(1,62) = 6.36$, $p = .014$). Planned comparisons showed that in the experimental group RTs were shorter for informative than uninformative trials ($t(31) = -3.01$, $p = .005$), but that this was not true in the control group ($t(31) = .075$, $p = .941$). This pattern suggests that children used information carried by the agreeing verb-form in an informative visual context to speed their word recognition. However, as the 1500 ms window in which RT was measured included the noun, a reaction time advantage may reflect either a predictive or an integrative facilitation process. In order to distinguish between these accounts in this task, it is necessary to look for effects during a window that does not include bottom-up information from the noun itself.

Switch Proportions

In order to address this difficulty, we analyzed children's tendency to switch from one picture to another during the determiner-adjective window. Figure 4 shows mean switch proportions for both distractor-to-target and target-to-distractor shifts, during informative and uninformative trials, graphed separately for the experimental and control groups. The pattern is clear: children were more likely to shift from the distractor to the target in informative trials in the experimental, but not in the control group. As predicted, there were no differences across conditions in children's tendency to shift from the target to the distractor. These patterns were supported by a 2x2 mixed effects ANOVA for each type of switch, distractor-to-target (D-T), and target-to-distractor (T-D). For D-T switches, the ANOVA revealed a significant main effect of group ($F(1,62) = 4.65$, $p = .035$), a marginal main effect of informativeness ($F(1,62) = 2.83$, $p = .097$), and a significant interaction between informativeness and group ($F(1,62) = 6.79$, $p = .011$)[4]. Planned comparisons showed that the proportion of D-T switches was higher for informative than uninformative trials in the experimental group ($t(31) = 3.34$, $p = .002$), but not in the control group ($t(31) = -0.60$, $p = .552$). No significant or marginal effects were found in the corresponding ANOVA for T-D switches (all Fs < 1.1). Recall that switch proportions were calculated in the 767 ms determiner-adjective window, which ended 300 ms after the average onset of the noun, before visual fixations could plausibly be driven by recognition of the noun itself. Thus the increase in distractor-to-target switches in informative trials for the experimental group only is evidence that children used the information carried by the number-marked verb *predictively*, to reject a number-mismatching picture based only on the number-marking on the verb.

Accuracy

Finally, we analyzed children's accuracy during two key windows. Children showed no difference in accuracy during the determiner-adjective window (experimental: informative mean = .53 ($SD = .09$), uninformative mean = .50 (.09); control: inf. mean = .50 (.10), uninf. mean = .48 (.10)). During the noun window, on the other hand, children in the experimental (inf. mean = .76 (.09), uninf. mean = .71 (.09)) but not the control group (inf. mean = .75 (.09), uninf. mean = .76 (.09)) were more accurate in informative

[4] All analyses of switch proportions were also conducted on arcsine transformed data. Analyses of the transformed and untransformed data revealed the same effects. For ease of interpretation the untransformed values are reported here.

than uninformative trials. A 2x2 mixed effects ANOVA conducted for each window supported this pattern. For the determiner-adjective window, this analysis yielded no significant effects (all Fs < 2.6). For the noun window, this analysis revealed a significant interaction between informativeness and group ($F(1,62) = 5.22$, $p = .026$). Planned comparisons showed that accuracy in the noun window was higher in informative than in uninformative trials in the experimental group ($t(31) = 2.56$, $p = .016$), but not in the control group ($t(31) = -.76$, $p = .45$). Thus, in addition to supporting faster reaction times and a higher probability of switches away from a distractor, the presence of a number-marked verb in an informative context supports a greater proportion of looks to the correct picture during the noun window.

Plurality Analyses

In order to assess the separate contributions of singular and plural trials to our results, for each of the measures above, we conducted a 3-way mixed effects ANOVA to analyze the effects of group (experimental vs. control), informativeness (informative vs. uninformative), and plurality (singular vs. plural). For each measure informative and uninformative trial means for both groups are shown in Table 2, separately for singular and plural trials.

Reaction time. For reaction time the interaction of informativeness and group in the main analyses appears to have been carried by the plural trials. That is, the patterns that we saw in the data as a whole are much more clearly present in plural than in singular trials. This was supported by a 3-way mixed effects ANOVA, which revealed a significant effect of informativeness ($F(1,54) = 5.27$, $p = .026$), and a marginal 3-way interaction ($F(1,54) = 3.90$, $p = .054$). Because our predicted effect is crucially an interaction between group and informativeness, to better understand the 3-way interaction, we followed up with 2-way ANOVAs (informativeness x group) for singular and plural trials separately. For plural trials, reaction time patterned much as it did for the data-set as a whole: the control group showed no difference in reaction time between informative and uninformative trials, while the experimental group showed faster reaction times in the informative than the uninformative trials. See means in Table 2. A 2x2 mixed effects ANOVA supported this pattern, showing a marginal main effect of informativeness ($F(1,58) = 3.91$, $p = .053$), and a significant interaction of informativeness and group ($F(1,58) = 4.51$, $p = .038$). In contrast, for singular trials, the corresponding analysis revealed no significant effects whatsoever (all Fs < 1). Further comparisons of the plural trials revealed that reaction times in informative trials were faster for the experimental ($t(31) = -2.92$, $p = .006$), but not the control group ($t(27) = .10$, $p = .92$). This suggests that the reaction time effects we found in the main analysis were carried largely by the plural trials.

Shift probability. To determine whether the effects on shift probabilities were also driven by the plural trials, we conducted a similar 3-way mixed effects ANOVA (informativeness x plurality x group) for both distractor-to-target (D-T) and target-to-distractor (T-D) shifts. For D-T shifts, this analysis revealed a marginal interaction of informativeness and group ($F(1,60) = 3.98$, $p = .051$), and a significant 3-way interaction of informativeness, plurality and group ($F(1,60) = 5.84$, $p = .019$). Again, to determine whether our predicted interaction was present in plural and singular trials separately, we conducted two 2-way mixed effects ANOVAs. Among plural trials these analyses revealed a significant interaction of informativeness and group ($F(1,61) = 7.71$, $p = .007$).

Among singular trials, the proportion of trials with a distracter-to-target shift showed no effect of informativeness, nor any interaction (all Fs < 1). Further comparisons within the plural trials showed that D-T shifts were more likely in the informative than the uninformative trials for the experimental ($t(31) = 2.90$, $p = .007$), but not the control group ($t(30) = -1.12$, $p = .271$). Children in the experimental but not in the control group showed an increased tendency to switch from distractor to target during the determiner-adjective window. As in the main analyses, there were no significant effects in similar analyses of T-D switches (all Fs < 1.7).

Accuracy. The patterns for accuracy are a bit different. For our accuracy measures, we also conducted a 3-way ANOVA to examine the effects of plurality. For the determiner-adjective window, this analysis revealed a significant interaction of plurality and group ($F(1,62) = 4.50$, $p = .038$), and a significant 3-way interaction of informativeness, plurality and group ($F(1,62) = 4.63$, $p = .036$). Again, separate 2-way ANOVAs were conducted for singular and plural trials. Analyzed separately, there were no effects on determiner-adjective accuracy in either singular or plural trials (all Fs $<$ 2.75). The 3-way ANOVA for accuracy during the noun window, in contrast, showed a significant interaction of informativeness and group ($F(1,62) = 5.03$, $p = .028$), but no 3-way interaction ($F(1,62) = .28$, $p = .598$). Again, 2x2 ANOVAs were conducted for singular and plural trials separately. Noun accuracy in plural trials showed a marginal interaction of informativeness and group ($F(1,62) = 3.81$, $p = .056$). In singular trials there was a marginal main effect of informativeness ($F(1,62) = 3.05$, $p = .086$), but no significant interaction ($F(1,62) = 1.22$, $p = .274$). Among singular trials, further comparisons showed that accuracy during the noun window was higher in the informative than the uninformative trials for the experimental ($t(31) = 2.23$, $p = .033$), but not the control group ($t(31) = .42$, $p = .679$).

In summary, 3-year-olds in the experimental group were both quicker and more likely to shift away from the distractor picture when the test sentence had an informative number-marked verb. This advantage was reflected in the latencies of distractor-to-target shifts (RTs), the proportion of distractor-initial trials with a distractor-to-target shift within the determiner-adjective window, and accuracy measured during the noun window. The effect measured on shift probability occurred even before the onset of the noun, providing evidence that children use the information carried by verb number agreement to make predictions about upcoming words. These effects were largely carried by plural trials.

Discussion

Three-year-olds used the information carried by a number-marked verb to anticipate features of the upcoming noun, looking away from a mismatching distractor picture more quickly and more often, with effects emerging even before the onset of the noun itself. By examining children's use of this cue in comprehension, we aimed to address two goals. First, we wanted to extend research on children's use of morphosyntactic cues in online language comprehension. Previous research on children's online use of morphosyntactic cues had focused on the very local and regular relationship between a determiner and a noun. By investigating children's use of subject-verb agreement, we have shown that children are able to take advantage of a less local, less regularly marked cue in online comprehension. Second, the greater syntactic distance between the dependent elements in subject-verb agreement allowed us to ask whether children use morphosyntactic cues predictively in online comprehension. Children showed that they were able to do both of these things. Reaction times were faster and accuracy was higher in trials with an informative number-marked verb than in trials without. Furthermore, even before they began to receive bottom-up information about the noun, children were more likely to switch their gaze away from a mismatching distractor picture toward the target.

This significantly expands what we know about children's rapid use of morphosyntactic cues in incremental sentence comprehension. They are not limited to very local and lexically consistent relationships, and they are able to use morphosyntactic cues predictively. Subject-verb agreement is less lexical, links elements in different major syntactic constituents and does so in a less consistent order. Nevertheless, 3-year-olds quickly used an informative agreeing verb to predict the number of an upcoming noun.

This finding is consistent with previous research suggesting that children can use verb agreement alone to compute the number features of the noun in context (Brandt-Kobele & Höhle, 2010; Legendre, et al. 2010), and joins these studies as some of the earliest data showing that children have this ability. It goes beyond these findings by showing that children use this information quickly online, as demonstrated by faster reaction times, higher shift probability and higher accuracy in the noun window, and by showing that children use it predictively, with effects on shift probability appearing before they begin to hear the noun. This feature of the data is consistent the few other findings that have allowed time to observe an effect of prediction. In particular, a recent study showed that French-learning 2.5-year-olds can use a gender-marked determiner to aid their identification of an upcoming noun, with effects appearing in an early window that encompassed the determiner, adjective and early part of the noun (Melançon & Shi, 2011). Furthermore, our data are consistent with the finding that children can use a semantically restrictive verb to anticipate an upcoming related noun (*You can drink the juice!*; Fernald, et al., 2008), and are not susceptible to the alternative interpretation of those results discussed in the introduction: that children might look to the target by virtue of its semantic relatedness alone, rather than as a result of a prediction that it will be named specifically as the object of the verb. In the case of *is* and *are*, the verb has very little semantic content at all, and the only cue is the morphological form of the verb. Thus, we have addressed both our goals: showing that children use subject-verb agreement in sentence interpretation, and that they can do so predictively.

Though we chose questions (*Where are the cookies?*) and locative inversions

(*There are the cookies!*) for their convenient order properties, children's use of the number-marked verb to anticipate the number properties of the subject in these structures suggests a further conclusion: that 3-year-olds have a flexible, abstract conception of the subject of the sentence. In canonical sentences, the subject is the first noun phrase encountered, and the verb follows. In this study, the subject was in a non-canonical position, coming at the end of the sentence, after the verb, but still controlling agreement. Children were sensitive to the dependency between the subject and verb despite the non-canonical ordering, suggesting that they understood the post-verb noun phrase in these sentences fulfills the same grammatical role as a pre-verbal canonical subject would.

One intriguing aspect of our data is a consistent tendency for the 3-way interactions between informativeness, plurality and group to be marginal, and, when analyzed separately, for the plural trials to show the same patterns as the data-set as a whole, while singular trials showed only a marginal main effect of informativeness on accuracy in the noun window. There are many reasons to expect verbs marked for plural agreement to generate stronger predictions than verbs marked for singular agreement.

First, it may be that children in our study are exposed to a dialect of American English in which the (standard) singular form of BE appears paired with a plural noun in some sentence contexts (e.g., *There's three cookies over there.*). Such patterns are common in various dialects of English, and they tend to be strongest in existential sentences and locative inversions (e.g., *There is, There's*), and to be asymmetrical, such that the singular form of the verb is more likely to be used with plural subjects (*There's three cookies.*) than the plural form is to be used with singular subjects (*?*There are one cookie.*; Hay & Schreier, 2004). Such experience might teach children that *is* does not strongly predict noun number, since they hear it paired with both singular and plural subjects, whereas the plural form *are* does consistently predict a plural noun. In this case, children would treat *There is* sentences as less informative, because in their experience, a sentence with that beginning could be continued equally well with either a singular or a plural referent.

Second, there is a sense in which the singular is necessarily less informative in our trials. For example, when children are looking at a picture of two cookies and hear *is*, it could be that the speaker is referring to just one of the two cookies. In contrast, when children are looking at a picture of one cookie and hear *are*, there are no alternative explanations available. If the speaker wanted to refer to the single object in that picture, she would necessarily use *is*. This makes *are* in the context of a single object a clearer mismatch. This asymmetry is inherent in the semantics of number. Where there are two cookies, there will always be one, and where there is only one cookie, there cannot be more than one.

Finally, and most interestingly, it is possible that 3-year-olds, like adults, treat the singular as the grammatical default (e.g., Eberhard, 1997)[5]. Number is marked directly on nouns, and the plural is the 'marked' variant (the one associated with an overt morphological marker, *dogs* as opposed to *dog*). Psycholinguistic evidence suggests that the plural is treated as the marked case in the process of checking agreement between subjects and verbs: For adults, plural but not singular local nouns attract agreement errors in both production and comprehension: *The key to the cabinets *are rusty* is a more

[5] In contrast, the plural has been proposed to be the semantic default (Sauerland, Anderssen & Yatsushiro, 2005; Bale, Gagnon & Kanjian, 2011). To the extent that these arguments are each valid, the psycholinguistic finding that the plural behaves as the marked value suggests that verb agreement is treated as a syntactic, rather than a semantic relationship.

common production error than *The keys to the cabinet *is rusty* (Bock & Miller, 1991), and is more likely to be overlooked in reading (Pearlmutter, Garnsey & Bock, 1991; Wagers, Lau & Phillips, 2009). Though at least two different mechanisms of agreement have been proposed to account for the frequency of this error, both accounts agree that a plural noun has a number feature marked as *plural*, whereas for singular nouns that feature is either absent or blank. This overt marking means that the verb is more likely to illicitly take on the *plural* value in production, and that an intervening plural noun is more likely to be retrieved in place of the proper, singular subject in the context of an erroneous verb during comprehension (Bock & Miller, 1991; Pearlmutter, Garnsey & Bock, 1999; Wagers, Lau & Phillips, 2009). The asymmetry in our data raises the possibility that children also treat the plural as the marked value, making the singular less informative.

One question which this study does not address is what kind of knowledge supports children's rapid use of morphosyntactic cues in online comprehension. In discussions of incremental use of gender agreement, three possible routes have been proposed (e.g., Dahan, et al., 2000). All three possibilities are discussed in turn.

First, children's knowledge of the distributional patterns of their language and of the coocurrences of particular lexical items could support the effects of subject-verb agreement online (e.g., Pine & Lieven, 1997; Theakston, et al., 2003; Mintz, 2003). For instance, children might associate the word *are* with a set of known plural nouns and *is* with a set of known singular nouns. They could use such lexical associations to choose more quickly among the referential options when they hear an agreeing verb. This proposal requires that affixed forms (*dogs, cookies*) be encoded and tracked separately[6] from unaffixed forms (*dog, cookie*), but makes no appeal to abstract grammatical knowledge, only to distributional knowledge and the combinations of particular words and morphemes. This would make the computation of subject-verb agreement very similar to the case of gender agreement within the noun phrase. On this view, number is a property of the stored form of the word, much like grammatical gender is a property of individual nouns. Our use of *is* and *are* makes children's use of the lexical relationship more plausible, since these are so frequent, and are clearly distinct forms rather than being affixed variants of the same form. Testing children's ability to anticipate noun-number based on regular verb agreement (e.g., *go* vs. *goes*), where each form is individually far less common than *is* or *are*, as well as testing their ability to anticipate noun-number on novel nouns (e.g., *Where are the daxes?*) should help to determine whether the lexical distributional route contributes significantly to children's success in our task. Other proposed routes rely on more abstract categorical knowledge.

A second possibility is that children are familiar with the semantic and morphophonological correlates of plurality, and that upon hearing the verb *are*, they can activate a class of nouns sharing those properties (e.g., Haskell & MacDonald, 2003). This, like the lexical-distributional route, requires that singular and plural forms be stored separately, but on this view it is not their coocurrence with particular verb forms that matters, but rather the typicality of their morphophonological form or their meaning for the category they belong to (e.g., *hands* is a morphophonologically typical plural, while

[6] Note that though the question of whether adults continue to store affixed and unaffixed forms has been contentious, most theories assume that children must go through a stage where they store both. On one view, this ends when children figure out the rule that governs the affixation (Marcus, et al., 1992), and on the other, the forms continue to be stored separately (Rumelhart & McClelland, 1986).

feet is not). Testing children's ability to use verb-number to anticipate either nouns that share the morphophonological characteristics of plurality (e.g., *box,* compare *socks*), or nouns that share the semantic correlates without sharing the morphophonological ones (e.g., *group, team*) would help to determine whether children use this route.

The third proposed route is syntactic. On this account, children use the agreeing verb *are* to anticipate a noun with the syntactic property *plural* (e.g., Friederici & Jacobsen, 1999). Crucially, such a noun need not be semantically plural: English has a group of nouns which are grammatically plural whether they refer to one object or to more than one (e.g., *glasses*, in reference to a single pair of spectacles). If children used a syntactic route for their predictions in the current study, they should also be able to anticipate a grammatically plural noun on the basis of a number-marked verb, even if semantic plurality is held constant. For instance, given a display showing a single pair of glasses and a phone, and hearing *Where are...*, children using the syntactic route should look more quickly to the glasses, despite their semantic singularity. Because all three accounts make similar predictions for the current study, our data do not allow us to distinguish between them. Further research will be necessary to begin teasing these possibilities apart.

In conclusion, children in our study used the information carried by an agreeing verb (*is* or *are*) to anticipate the upcoming noun in questions and locative inversions (e.g., *Where are the good cookies?*). This shows that they are sensitive to the grammatical morphosyntactic dependency between the subject and the verb, that their concept of the subject of a sentence is abstract enough to include elements that follow the main verb, and finally that children engage in predictive processing during language comprehension.

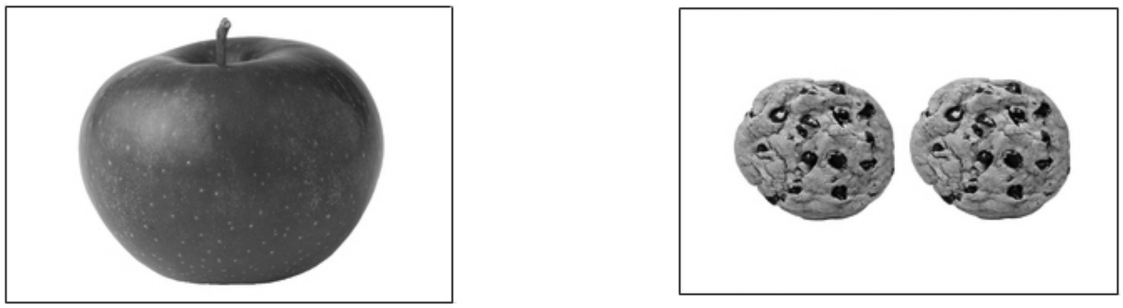
This is one of the earliest findings that children are able to infer semantic plurality from verb-number alone, and one of the first findings that children use information predictively during online language comprehension. With further research, we hope to better understand what knowledge children are using to support their rapid success with number-marked verbs in online comprehension.

Tables and Figures

	Singular	Plural
1st person	I walk	We walk
2nd person	You walk	(y'all) walk
3rd person	he/she/it **walks**	They walk

	Singular	Plural
1st person	I **am**	We are
2nd person	You are	(y'all) are
3rd person	he/she/it **is**	They are

Table 1: Regular and Irregular Verbal Paradigms in English. The majority of the forms in each paradigm are the same. In the regular paradigm only the 3rd person singular differs from the other forms, while in the irregular paradigm, only the 1st and 3rd person singular forms differ from the others.



Informative:	There are the good cookies!	*plural*
	There is the good apple!	*singular*
Uninformative:	Oh, look at the good cookies!	*plural*
	Oh, look at the good apple!	*singular*

Figure 1. Basic trial structure for the current study. Children were presented with two pictures and an accompanying sentence. Sentences could be informative (i.e. include a number-marked verb) or uninformative, and could name either the singular or the plural target.

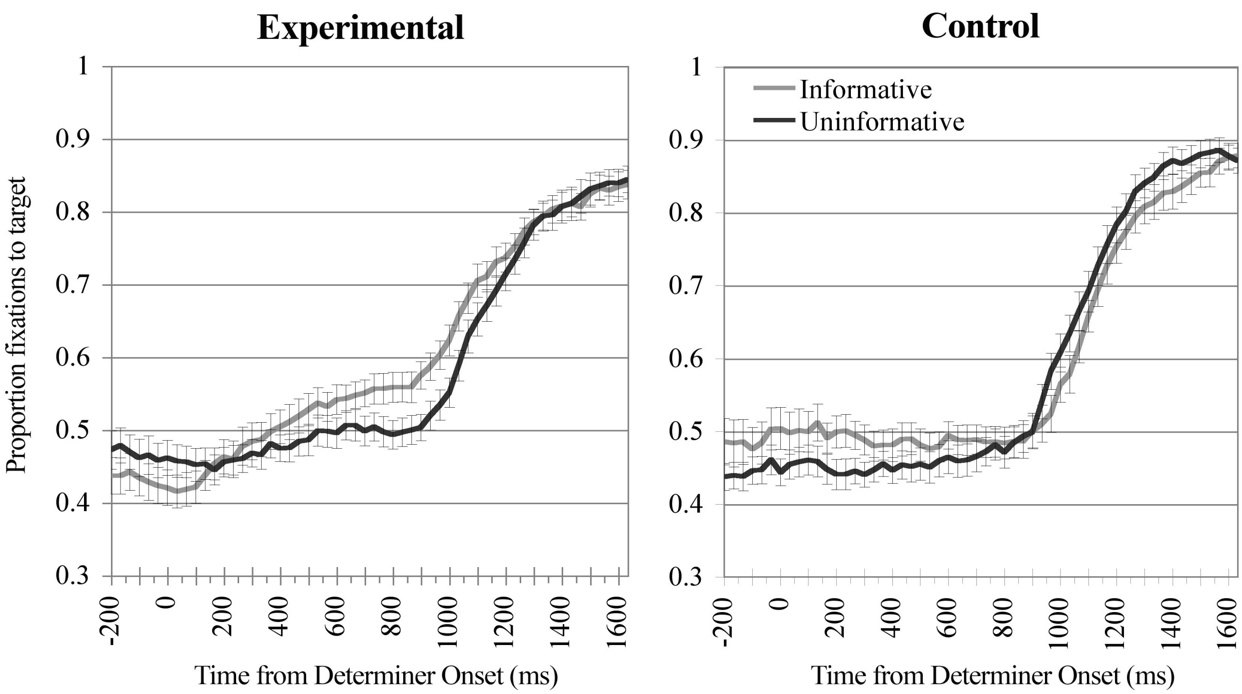


Figure 2. Proportion fixations to target. Proportion fixations to the target in informative and uninformative trials, graphed separately for control and experimental groups. The x-axis shows time measured from the determiner onset; average verb onset in informative trials precedes determiner onset by approximately 200 ms. Error bars represent standard error of the mean. The y-axis shows the proportion of all fixations directed to the target, in each 33 ms time-interval. Looks to the target increase earlier in informative trials in the experimental group.

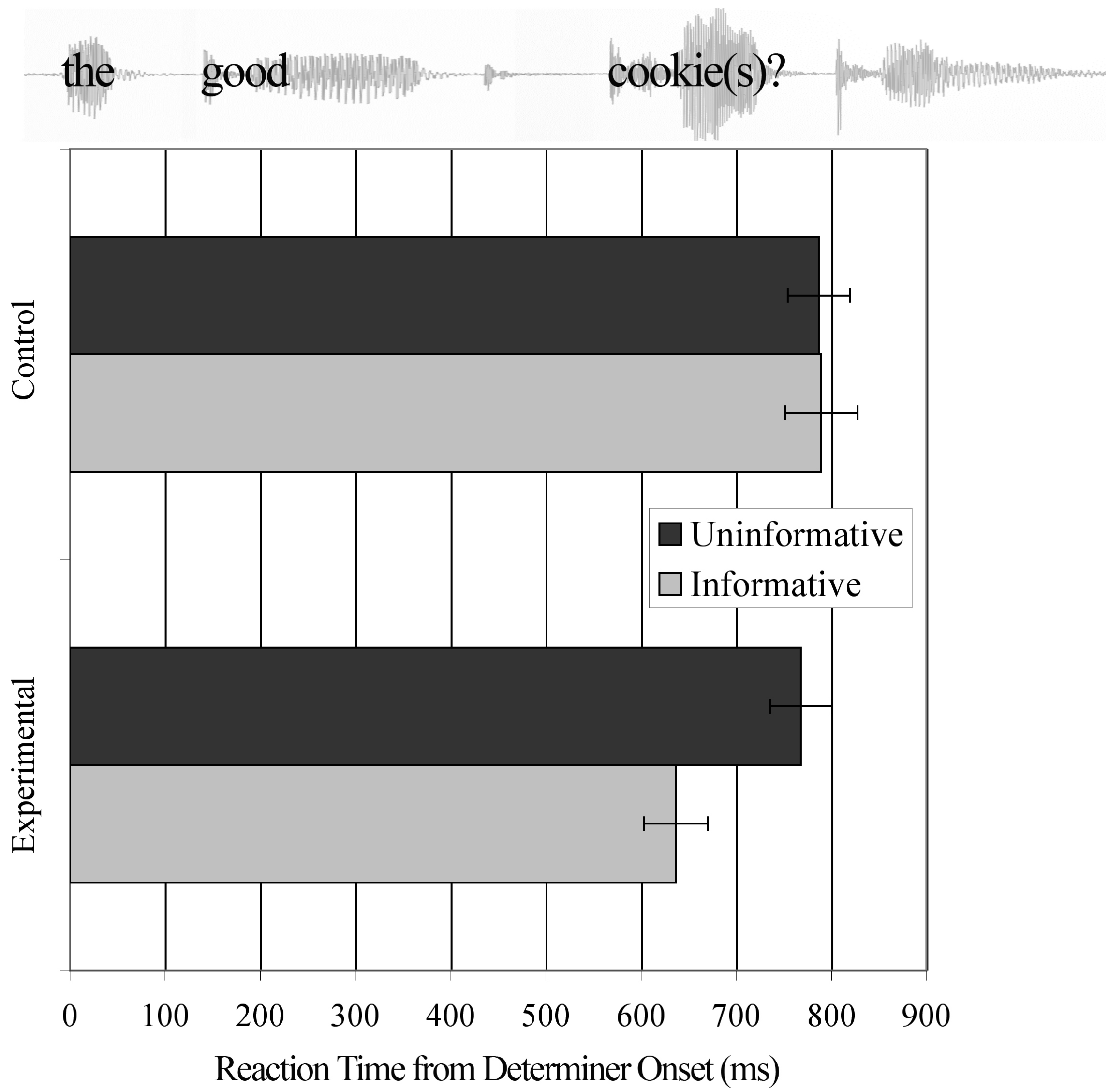


Figure 3. Reaction time from determiner onset. Reaction time from determiner onset in informative and uninformative trials for both experimental and control groups. The x-axis shows time from determiner onset in milliseconds. Error bars represent standard error of the mean. Reaction times for the control group and for uninformative sentences in the experimental group all pattern together. Informative sentences for the experimental group are faster.

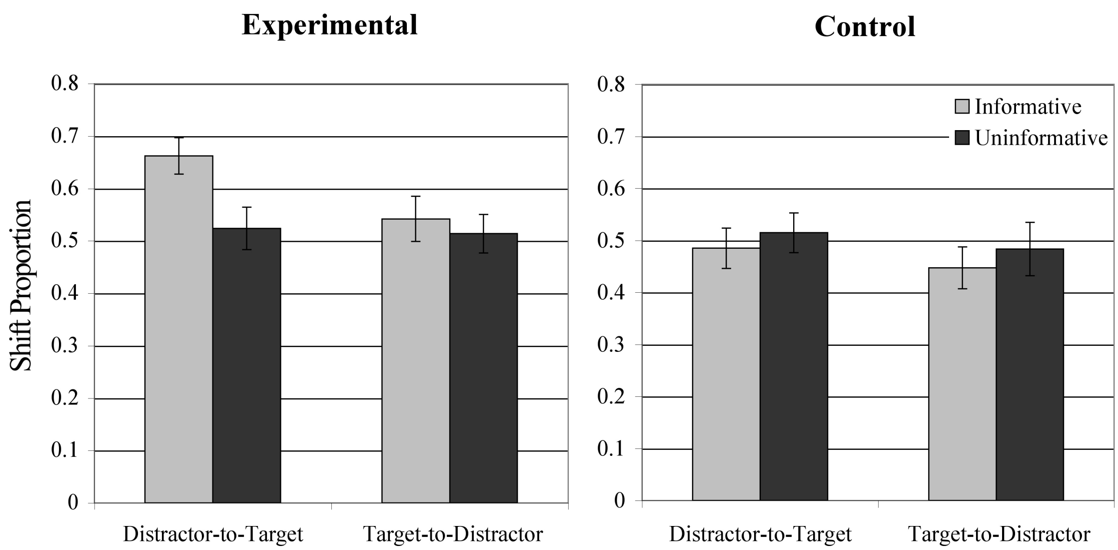


Figure 4. Shift Probability. Shift probability, showing both distractor-to-target and target-to-distractor switches for the experimental and control groups. The y-axis shows the proportion of trials that included a switch to the other picture during the determiner adjective window. Distractor-to-target switches were more likely in informative trials for the experimental group. In other trial types, children were approximately as likely to switch as not.

		Experimental		Control	
		Singular	Plural	Singular	Plural
Reaction Time (ms)	Informative	696 (239)	626 (315)	715 (253)	760 (267)
	Uninformative	691 (279)	822 (234)	789 (173)	787 (253)
Distractor-to-target Switch Proportion	Informative	.62 (.31)	.67 (.32)	.55 (.33)	.44 (.31)
	Uninformative	.58 (.30)	.45 (.31)	.49 (.25)	.53 (.29)
Target-to-distractor Switch Proportion	Informative	.48 (.36)	.55 (.28)	.49 (.26)	.42 (.30)
	Uninformative	.52 (.28)	.48 (.32)	.57 (.36)	.47 (.36)
Determiner-adjective Window Accuracy	Informative	.51 (.13)	.53 (.15)	.49 (.15)	.51 (.13)
	Uninformative	.53 (.14)	.47 (.15)	.44 (.13)	.52 (.17)
Noun Window Accuracy	Informative	.78 (.10)	.73 (.13)	.76 (.13)	.74 (.11)
	Uninformative	.73 (.12)	.70 (.12)	.75 (.11)	.78 (.13)

Table 2. Means for all measures, split by plurality. Means for each measure, shown separately for singular and plural trials. The number in parentheses shows standard deviation.

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